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MODIFICATION OF VISUAL EVOKED POTENTIALS OF THE RABBIT DURING ATTENTIVE BEHAVIOR

by

John Wilfred Urschel

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Modification of Visual Evoked Potentials of the Rabbit during Attentive Behavior" submitted by John Wilfred Urschel in partial fulfilment of the requirements for the degree of Master of Science.

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Abstract

Visual evoked potentials were investigated in a total of 16 New Zealand white, unanesthetized, partially restrained, rabbits under conditions which in humans would be likely to produce changes in "attention". The evoked potentials were recorded from the lateral geniculate body and visual cortex by means of chronically implanted bipolar stainless steel electrodes and stainless steel cortical screws. In one half of the animals the visual evoked potentials were elicited by a peripheral visual stimulus (flash of light), while in the other half of the animals the visual evoked potentials were elicited by a central stimulus (submaximal electrical stimulation to the optic chiasma). In one experiment designed to investigate the "distraction" phenomenon these stimuli were presented under three different conditions; auditory distraction condition (clicks preceded the potential evoking stimulus), visual distraction condition (flickering light preceded the potential evoking stimulus), and control conditions (stimulus alone). The "attention" phenomenon was investigated by pairing the stimulus which produced the evoked potential with a noxious stimulus (white noise). The evoked potentials were displayed on a Single-Beam cathode ray storage oscilloscope for amplitude measurement. Following the experiment the animals were perfused and the electrode sites were verified histologically.

A depression of visual evoked potentials was observed when either an auditory or visual distracting stimulus preceded the stimulus which produced the evoked potential (flash or optic chiasma stimulation).

When the animal was made to "attend" to the stimulus which produced the visual evoked potential an enhancement of the evoked potentials was observed. The results provide evidence which suggests that peripheral mechanisms, such as eye movement, and closing of the eyelid, etc., does not play an important role in the processes involved in the phenomena of "distraction" and "attention". Evidence has been obtained which suggests a greater likelihood that the processes involved, are controlled by a specific sensory filtering mechanism which operates via centrifugal fibers in the visual pathway. The results also provide indirect evidence which suggests that if centrifugal fibers terminate in the retina they do not appear to play an important role in these phenomena.

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Literature Survey

For many years anatomists have recognized that nearly all sensory systems have efferent fibers, known as centrifugal projections, passing from the central nervous system to the receptor organs of these sensory systems. Physiological analysis of the activity taking place within various relay stations between the peripheral nerves and the cerebral cortex revealed that the relay nuclei in the spinal cord (Therman, 1941), brain stem (McKinley and Magoun, 1942), and thalamus (Rose and Mountcastle, 1954), were reliable in their transmission of evoked signals. However, because until recently, physiological findings were derived from the examination of anesthetized animals it was believed that the sensory nerves and the central ascending paths conveyed to the cortex, unaltered, what ever messages were generated by the sensory end organs.

As early as 1904, Tello, writing about centrifugal fibers, which he believed carried impulses from the cortex to the lateral geniculate body stated: "It seems that their object is to regulate the afferent stream" (i.e., of nerve impulses), "and so limit the field of attention." In the same vain Brower in 1933, in a discussion of neuropathology stated:

> We accept that there is also a centrifugal side in the process of sensation, of vision, of hearing, and so on. I believe that a further analysis of these descending tracts to pure sensory centers will also help physiologists and psychologists to understand some of their experiments.

In 1953 Adrian expressed some interesting speculations about the physiological basis of attention. He was concerned, as we still are, with how the brain deals with the messages which reach it via the afferent pathways from the receptors.

> The operations of the brain seem to be related to particular fields of sensory information which vary from moment to moment with the shift of our attention. The signals from the sensory organs must be treated differently when we attend to them and when we do not and if we could decide where and how the divergence arises we should be nearer to understanding how the level of consciousness is reached.

He speculated that at some stage on their passage to consciousness the messages meet with barriers, or there is some editing in most of the sensory pathways. Adrian suggested two possibilities. One was that all afferent signals are allowed to reach the cortex and that at any moment the cortex would have a complete pattern of the environment at its disposal, but that there is some controlling mechanism to decide which sensory pattern should have priority. The other possibility was that the controlling mechanism operates at an earlier stage in the pathway and that we attend to a specific stimulus and are unaware of other stimuli because the signals set up by that stimulus are allowed to reach the cortex while the other signals are not.

One of the first observations of an electrophysiological correlate of "attention" was the alpha blocking response in man observed by Berger (1929). Further contributions were made by other investigators such as Rheinberger and Jasper (1937) who found that in unanesthetized cats, the electrogram from all regions was characterized by low amplitude higher frequency potentials when the animal showed behavioral

indications of being generally aroused or activated due either to controlled external stimuli or internal organic states. Relaxation was associated with a return to the slower rhythms while the pattern characteristic of sleep was similar to that described for man during sleep. Changes in the electrical activity of all regions of the cortex usually followed a single effective afferent stimulus although the changes in a given region could be more intense and of different form than those in other regions.

Adrian (1953) concluded however, that the EEG records made through the skull or surface of the unanesthetized brain tell us little about the complex effects of a shift of "attention" on brain activity.

Experimental studies to support the prophecies of Tello and Brower, and the hypothesis outlined by Adrian were soon forthcoming and provided physiological evidence that central mechanisms do influence the transmission of sensory information along some of the afferent pathways. Following the work of Granit and Kaada (1952), which demonstrated that the efferent gamma system is tonically activated from central regions and that stimulation of various central nervous structures influences the afferent discharge from the muscle spindles, Hagbarth and Kerr (1954) investigated whether or not such sensory regulating pathways were unique for muscle spindle afferents or whether they are more widespread and common in the nervous system. They also wondered whether it was reasonable to

to assume that not only the initiation, but also the synaptic transmission of afferent messages in the central nervous system might be under the influence of specific regulating mechanisms. Using curarized cats they investigated the feasibility of influencing a conducted afferent volley in the spinal cord by repetitive stimulation of various structures in the brain. Their results indicated that stimulation of the bulbar and midbrain reticular formation, the ventral part of the anterior vermis, the postcentral sensory cortex, the precentral motor cortex and the anterior part of the cingulate gyrus could, indeed, influence the size of an afferent volley evoked by a dorsal root stimulus and recorded from dorsal and ventral columns, midbrain, cerebellum and sensory cortex. They concluded that synaptic afferent transmission in the spinal cord can be influenced in a physiological manner by descending pathways from certain structures in the brain.

The possibility that a selective central inhibitory mechanism might operate during attention to filter sensory impulses in other afferent pathways was investigated by Hernández-Péon, Scherrer and Jouvet (1956) in their now, classical study on "attention". They studied afferent transmission in the cochlear nucleus (2nd or 3rd order neurons of the auditory pathway) by means of chronically implanted electrodes in unanesthetized unrestrained cats during experimentally elicited attentive behavior. Auditory clicks were delivered by a loud-speaker at regular intervals near the cat and the responses recorded in the cochlear nucleus. Three types of

sensory modalities were used to attract the animal's attention (or distract the animal's attention from the auditory stimulus): visual, olfactory, and somatic. During presentation of visual stimuli (two mice in a closed jar), the auditory responses in the cochlear nucleus were greatly reduced in amplitude in comparison with the control responses. When the mice were removed, the auditory responses returned to the same order of magnitude as the initial controls. Similarly, olfactory stimulation (piped in fish odors) and somatic stimulation (nociceptive shock to forepaw of cat) resulted in orientation (and presumably "attention") toward these stimuli with a marked reduction in amplitude of auditorily evoked responses in the cochlear nucleus. They concluded that if this sensory inhibition during attentive behavior, occurs in all other sensory paths except the ones concerned with the object of attention, such an inhibitory mechanism might lead to favoring of the stimuli from the attended object by the selective exclusion of incoming signals. Such a selective sensory inhibition might operate simultaneously for various sensory modalities, leaving one or more unaffected. Also the selectivity could extend to some discriminable aspects of any single modality--for example, to one tone and not to others. These observations suggested that the blocking of afferent impulses in the lower portions of the sensory path may be a mechanism whereby sensory stimuli out of the scope of attention can be markedly reduced while they are still in their trajectory toward higher levels of

the central nervous system. Such a central inhibitory mechanism could, therefore, play an important role in selective exclusion of sensory messages along their passage towards mechanisms of perception and consciousness in the manner postulated by Adrian (1953).

Hernández-Peón, Scherrer and Velasco (1956) explored other forms of afferent transmission. Using curarized cats they studied afferent evoked potentials in the somatic and visual systems. In the somatic study they obtained recordings, by means of bipolar electrodes in the gracilis nucleus while stimulating the corresponding dorsal column about 20 mm. below with similar electrodes. Records were also obtained from the sensory trigeminal nucleus while a branch of the infraorbital nerve was stimulated in a similar manner. In each series of animals they also studied the effect of brain stem lesions. In a third group of animals recordings were taken from the optic tract and the lateral geniculate body with stereotaxically placed bipolar electrodes. Photic stimulation consisted of strobotax flashes at regular time intervals. Their findings were as follows: Brain stem tegmentum and sensory motor cortex stimulation led to a depression in the secondary wave of the evoked potential at the gracilis nucleus produced by an afferent volley from the dorsal column while the pre-synaptic spike was unchanged. A lesion of the mesencephalic reticular formation (producing a sleep pattern in the EEG) resulted in an increase of the secondary wave of the potential recorded from the trigeminal sensory nucleus, while the pre-synaptic spike remained

unchanged. Similar effects were produced by deep Nembutal anesthesia. Electrical stimulation of the mesencephalic reticular formation and visual cortex depressed photic evoked potentials recorded from the lateral geniculate body and visual cortex, while the potentials at the optic tract were either potentiated or depressed. Nembutal anesthesia depressed optic tract potentials but enhanced those obtained at the lateral geniculate body. From the above findings they concluded that sensory inhibition upon the first somatic sensory synapse and upon the thalamic visual synapse is acting tonically during wakefulness and requires functional integrity of the brain stem reticular system. They also concluded that activation of the brain stem reticular system inhibits sensory transmission at the gracilis nucleus at the lateral geniculate body and at the retina, similar to what had been previously shown at the spinal cord and at the sensory trigeminal nucleus. They further concluded that potentiation can also be produced at the retina.

It might be added, that at an earlier date, Granit (1955), encouraged by his successful stimulation of centrifugal gamma fibers of the muscle spindles from the brain, did a study on the effects of centrifugal and antidromic stimulation of the visual pathway. He found that electrical stimulation of the reticular substance in the mesencephalic tegmentum could cause a lasting augmentation of the frequency of firing of individual ganglion cells or an inhibition of photically induced activity of some ganglion cells in the retina.

In 1957 Hernández-Péon, Guzman-Flores, Alcaraz and Fernandez-Guardiola (1957) investigated sensory transmission in the visual pathway in somewhat greater detail. They recorded photic evoked potentials from the optic tract, lateral geniculate body and visual cortex in unanesthetized cats by means of chronic bipolar electrodes. The photic stimuli consisted of short and long flashes of light. Attentive behavior was elicited from the animal by acoustic and olfactory stimuli. Similar behavior could be elicited by stimulating the mesencephalic reticular formation through implanted bipolar electrodes. The results obtained were in keeping with those obtained in the auditory system. There was a depression of the photically evoked potentials recorded from the cortex, lateral geniculate body and optic tract during attention to acoustic and olfactory stimuli as well as electric stimulation of the mesencephalic reticular formation. They suggested that the observed afferent blockade during attention is the result of centrifugal fibers to the retina, probably of inhibitory function. It was further suggested that this influence came from the brain stem reticular system, the reticular system in turn being controlled by the cerebral cortex.

Hernández-Peón, Guzmán-Flores, Alcaraz, and Fernández-Guardiola (1958), carried out experiments on habituation in the visual system. Using similar techniques as in other studies they found that after several hundred to several thousand repititions of a flash of light, the potentials evoked in the lateral geniculate body and visual

cortex were diminished. Although these authors observed no reduction at the optic tract, this effect was seen in a later study by Palestini, Davidovich, and Hernández-Peón (1959). This effect differs from adaptation or fatigue in that it is specific to the stimulus pattern utilized. It was found that after habituation to a bright flash of light, a dimmer flash would produce dishabituation (recovery of the potentials to the previous amplitude). This verified the findings of habituation in the auditory system at the dorsal cochlear nucleus (Hernández-Peón, Jouvet and Scherrer, 1957). They found dishabituation could occur in several ways: spontaneously, with the passage of time; by "dishabituation", by novel stimuli which evoked orienting responses; by barbiturate anesthesia; and by lesions in the mesencephalic reticular formation. They regarded afferent neural habituation as a form of simple learning. They suggested that the effects noted could be accounted for in terms of centrifugal inhibition of retinal neurons by a mechanism involving the brain stem reticular formation. In this way, they maintained, there were striking similarities between habituation and the afferent "blocking" in attention.

Fernández-Guardiola, Roldán, Fanjul, and Castells (1961) further investigated the phenomenon of habituation and their findings challenged the general hypothesis of neural inhibition as postulated by Hernández-Peón and his associates. They carried out a study using intact cats (chronic electrode preparations) as well as encéphale isolé preparations. Two types of repetitive stimulation were used: flashes of light and

brief electrical stimulation applied to the optic chiasma. Habituation was attempted in animals with normal pupillary motility and in animals with atropine produced mydriasis. Evoked potentials were recorded from the visual cortex and lateral geniculate body. They found that in all cases depression of the evoked potential was first seen at the cortex, followed by synchronization of the EEG. Absence of pupillary motility prevented the habituation process to visual stimuli in both the chronic and acute preparations. Depression of the evoked cortical potentials during repetitive electrical stimulation of the chiasma was minimal as compared with the depression obtained by flash stimulation. These findings suggest that habituation is not due to the same central inhibitory mechanism. Hernández-Péon and his associates had proposed that this phenomenon was due to an inhibitory centrifugal fiber mechanism functioning at the retinal level. However, the results obtained in the study by Fernández-Guardiola et al, (1961) indicated that the pupillary mechanisms of the eye, and not the retinal inhibitory mechanisms, were involved in habituation.

The possibility exists that the depression of evoked potentials during distraction is also due to peripheral mechanisms. EEG observations suggest, however, that two different mechanisms are involved, i.e., during habituation there is a complete state of synchronization while during distraction there is a state of desynchronization of the EEG. However, until the role of peripheral mechanisms in distraction is specifically investigated this hypothesis cannot be ruled out.

The question of the functional significance of the postulated centrifugal influence upon the retina was further investigated by Palestini, Davidovich, and Hernández-Peón (1959) in a study on unanesthetized cats. They implanted bipolar electrodes in the optic tract and mesencephalic reticular formation. Four or five days later the cat was immobilized in a hammock with its head fixed and its pupils dilated with homatropine. The head was placed in a shiny metalic cone to allow diffuse light reflection. A series of conditioning experiments were carried out. A technique of conditioning similar to "classical conditioning" was used, except that no overt responses were measured. Four intermittent flashes of light were used as the conditional stimulus while the unconditional stimulus was an unavoidable electric shock delivered to the skin of one leg ("nociceptive" stimulus). Focusing of attention was elicited by means of olfactory stimuli (fish odor) and visual stimuli (white rat or white piece of cotton in a jar between cat and light source). They also investigated photic habituation in which they presented photic stimuli in monotonous repetition (several thousand times). Their findings were as follows: The optic tract potentials evoked by brief flashes of light were diminished during attentive behavior elicited by olfactory, nociceptive, and visual stimuli (distracting phenomenon). Monotonous repetitive flashes of light resulted in reduction of optic tract potentials or habituation. This was in keeping with habituation observed at the cochlear nucleus (Galambos et al, 1956). Repeated association of four flahses of

light with a nociceptive electric shock during the fourth flash resulted in potentiation of the initially reduced third and fourth potentials in each series (attention phenomenon). Because both visual and non-visual distracting stimuli depressed the evoked potentials recorded, they postulated that the depression was due to efferent impulses transmitted to the retina via the centrifugal fibers from the controlling centers in the central nervous system. They speculated that there were two sets of centrifugal fibers, inhibitory and facilitatory, running to the retina. The inhibitory fibers would function during the "distraction" phenomenon while the facilitatory fibers would transmit impulses to the retina during the phenomenon of "attention". In other words, they postulated a selective filtering process within the visual system acting primarily at the retina. However, the depression of evoked potentials that occurred following visual distraction could be due to other less complex factors such as eye movement and other peripheral mechanisms. This possibility is in need of further investigation, especially, in view of the fact that the study by Palestine et al.,(1959), and that by Fernández-Guardiola et al.,(1961) provided conflicting results on habituation. The former group reported that habituation was possible with pupillary dilatation while the latter group found that visual habituation would only occur in the undilated pupil. These results are difficult to reconcile.

A further problem that this hypothesis encounters is the fact that there is still not complete agreement as to the central course of the centrifugal fibers or as to whether or not they transmit impulses to the retina. Dogiel (1895) and Cajal (1904) were convinced of their termination in the retina while Polyak (1941) felt that they had not yet been convincingly demonstrated in the optic nerve and tract. Polyak (1957) states:

> Certain fibers resembling arborization of axons, apparently originating outside the retina, possibly in the midbrain may be the structures through which the retina is influenced by the brain....This is most probable in the case of avian retinae. It is less certain in other Vertebrates, particularly Mammals. However, similar teledendron-like terminal arborizations have been found by this author in the retina of the Chimpanzee....When, in Man, an eye has been missing for a long period of time, the optic nerve of that side shows complete degeneration and absence of all myelinated fibers when stained for myelin. Since it is probable that in the human optic nerve all fibers are myelinated, this could be interpreted to mean that there is no centrifugal fiber system. The evidence, however, is not conclusive, since there is possibly a retrograde degeneration of centrifugal fibers whose terminals have been cut off.

Brindley (1962) states:

> Anatomical evidence commonly accepted as favoring it consists of observations that tend to show that some of the fibers of the optic nerve have their cell bodies in the brain. Many of the physiological observations that have been held to favor the hypothesis of centrifugal fibers can be explained by other means.

Jacobson and Gestring (1958b) carried out a study, on lightly anesthetized cats, which appeared to be strong evidence that activity of the cat's retina could be modified by impulses passing to the eye along the optic nerve. They observed that section of the intracranial

part of one optic nerve caused an immediate increase in amplitude of the electroretinogram of the eye whose nerve has been cut, without affecting that of the other eye. Brindley and Hamasaki (1962) were unable to confirm these findings in a similar study using unanesthetized cats. They concluded that section of one optic nerve in front of the optic chiasma has no effect on the electroretinograms produced by regularly repeated short bright flashes of light. Also, it was noted, that pentobarbitone can produce equal increases in the amplitudes of the electroretinograms of right and left eyes when one optic nerve has been cut through and the other is intact.

It would appear, therefore, that the point of termination of centrifugal fibers in the visual system has not been adequately established as yet. One must question the validity of the conclusions that the observed potentiation or depression of potentials at the optic tract were mediated by centrifugal fibers running to the retina.

There appears to be, however, more complete agreement on the course and function of the centrifugal fibers at the lateral geniculate body. Arden and Söderberg (1961) working with encéphale isolé and cerveau isolé preparations in rabbits recorded responses in single lateral geniculate body cells (with microelectrodes) under conditions in which the nervous input to the lateral geniculate body could be controlled. The input could be reduced, by section of parts of the brain or by removal of retinal activity through retinal ischemia, or increased by photic or

auditory stimulation or electrical stimulation of the brain stem. They found evidence of a "second input" to the geniculate body from the midbrain reticular activating system and cerebral cortex. The study suggested that this input is more important than the optic nerve in the maintenance of the resting activity of the lateral geniculate cells, and that stimuli that cause arousal or supposed changes in attention can greatly influence the discharge rate. They concluded that the lateral geniculate body appears to act as an interpreter, recorder, and mixer of retinal information. This study confirmed the anatomical findings of Scheibel and Scheibel (1958) who demonstrated the presence of reticulogeniculate fibers.

This modifying effect of the lateral geniculate body of visual messages on their way to the cerebral cortex from the retina was further confirmed by Ogawa (1963). Using lightly anesthetized paralyzed cats he recorded the responses, produced by a photic stimulus, from single lateral geniculate cells and optic tract axons (with microelectrodes) while he stimulated the mesencephalic reticular formation. He found that reticular formation stimulation caused an increase in excitatory activity at the lateral geniculate body as evidenced by increase in firing rate. This effect was easily abolished by deepening the anesthetic. He found, however, that reticular formation stimulation failed to produce any excitation at the optic tract axon level.

The phenomena studied by Hernández-Péon from 1956 to 1959 were further investigated by Horn (1960). Horn questioned the method of assessment of "attentive" behavior in the studies carried out by the former researchers. His aim was to clarify the problem of whether the depression of an evoked response occurred because that sensory modality was used to examine the sensory field (a type of orienting behavior or arousal) or whether the depression was due to the filtering process advanced by Adrian and supported by Hernández-Péon. He measured the changes in the cortical evoked responses to a light flash in unanesthetized cats; while their behavior was directed toward an object (mouse) in the visual field, while the animals were relaxed, while the animals were moving spontaneously, and while a conditioned stimulus (tone) was being presented. He recorded the evoked responses by means of a monopolar cortical electrode. Ten experimental responses were selected at random and ten control evoked responses were similarly selected from the resting animal. His findings were as follows: When the mouse was being shown, the oscillations of the background ECoG were reduced in amplitude though their frequency remained unchanged. The amplitude of all components of the evoked response was also reduced. Movement of the cat without "attention" or orientational behavior did not produce a depression of the evoked response, ruling out muscular activity as a causative factor. Pupillary changes occurring on accommodation while looking at the mouse were also ruled out as

a factor causing depression in the evoked potentials. During the phase of early conditioning to the tones when the cat showed visual searching behavior there was a reduction in amplitude of both the background ECoG and the evoked response. During the phase of late conditioning when no visual searching was present only the background ECoG showed significant reduction in amplitude. He also observed a spontaneous variation in the evoked responses at the visual cortex in the resting animal.

Horn concluded that photically evoked responses in the visual cortex are not attenuated when a cat's behavior is orientated to an acoustic stimulus, so long as there is no visual searching component in the animal's behavior. On the other hand, when the animal's behavior is directed to a stimulus in the visual field, or shows some visual searching in response to a non-visual stimulus, evoked potentials are reduced in amplitude.

The failure to find a depression of evoked potentials when the animal was no longer displaying visual searching was interpreted by Horn as evidence against Hernández-Péon's hypothesis of a sensory filtering mechanism. An alternative explanation, of Horn's finding, could be that the animal might have simply ceased to attend to the distracting stimulus during the late phase of the conditioning procedure. Horn assumed, however, that the animal was still attending to the distracting stimulus at this point. According to Hernández-Péon's hypothesis this lack of "attention" would have resulted in the absence of the characteristic

depression of the evoked potentials noted early in the conditioning procedure.

It is worth noting that, although, Horn's finding, of depression of evoked potentials following a visual distraction, is in complete agreement with the work of Hernández-Péon and his associates, (Palestini, Davidovich, and Hernández-Péon, 1959), the explanations of this finding are completely different. Hernández-Péon and his associates felt it was due to a specific filtering mechanism functioning at the retina via inhibitory and facilitatory centrifugal fibers. Horn's hypothesis, on the other hand, was that the reduction of evoked potentials is a correlate of the searching for visual information or of the increase in general arousal and not because the visual information is irrelevant and thus filtered out.

The disagreement between Horn and Hernández-Péon appears to be largely on a theoretical basis. The former equates the attenuation of visual evoked potentials during visual distraction with an increase in the amount of visual information which reaches the cerebral cortex. Hernández-Péon, on the other hand, equates such attenuation with a reduction in the amount of visual information which reaches the cerebral cortex. Work by Jouvet and Courjon (1958), and Jouvet and Lapras (1959), tends to support the latter hypothesis. Working with human subjects, they instructed them to count the number of stimuli (this served to make the subject "pay attention" to the stimuli) and found a correlation between the amplitude of the evoked

potential and the reported awareness of the stimuli. In other words, the subjects reported more visual information when the evoked potentials were of greater amplitude and when they were "paying attention". These results lend support to the hypothesis advanced by Hernández-Péon rather than that advanced by Horn.

The most recent work in this area, done by Spong, Haider, and Lindsley (1965), also supports the findings of Hernández-Péon and his associates. Lindsley et al., used human subjects and recorded a conventional EEG and averaged the evoked potentials obtained in response to repeated stimulation. The EEG was obtained from the occipital and temporal areas while the subjects were attending to flashes and ignoring clicks and visa versa. This was done by having the subjects perform under conditions of vigilance, key-pressing, and counting. Under all conditions, alternating clicks and flashes were presented 1 sec. apart. They found that responses to flashes recorded from the occipital area were larger when attention was directed toward visual stimuli and responses to click stimuli recorded from the temporal area were larger when attention was directed toward auditory stimuli.

In summary, it would appear that most authors agree that there exists a neural mechanism, within the brain, which is capable of filtering out irrelevant sensory information during attention to other more relevant sensory stimuli. Complete agreement and understanding of how and where such a neural mechanism

operates is, however, still lacking. It would appear that studies in the past have failed to adequately determine the role of the peripheral mechanisms in this phenomenon. In addition, more information is required before one can adequately differentiate between a general and specific filtering process. Only future investigation, of this interesting aspect of brain function, can provide the answer to these questions.

Material and Methods

A. Experimental Plan

Visual evoked potentials were investigated in unanesthetized rabbits under conditions which in humans would be likely to produce changes in "attention". The general aim of these studies was to analyze some of the properties of the physiological mechanism responsible for alterations in evoked potentials with shifts of attention.

More specifically, studies were carried out to determine to what extent this physiological mechanism depends on peripheral visual mechanisms, i.e., pupillary changes, eye movement, and gross movements associated with the orienting response. These studies were also designed to determine whether the inhibitory effects of "distracting" stimuli were a generalized one or whether this mechanism can operate selectively within a given sensory modality. In other words, is there a generalized inhibition of the whole visual system when a distracting stimulus precedes the visual stimulus which evokes the potential? On the other hand, it is possible, that a selective filtering mechanism might operate within the visual system, so that when a visual distracting stimulus precedes the visual stimulus which evokes the potential there is a selective facilitation of that part of the visual system which transmits impulses from the distracting visual stimulus with an inhibition of other parts of the visual system. Another aim was to determine the alterations in evoked potentials when the

animal's "attention" is focused on the stimulus which evokes the potential.

To achieve some of these aims, experiments were set up to make the following comparisons of visual evoked potentials;

(a) To compare the amplitude of visual evoked potentials obtained in rabbits when a stimulus is given alone, with that obtained when an auditory or visual stimulus precedes the stimulus which evokes the potential.

(b) To compare the amplitude of visual evoked potentials recorded under the above circumstances when specific measures are taken to control peripheral visual mechanisms. These specific measures were to include the following factors: dilation of the pupil, control of the location and position of the rabbit in relation to the stimulus by placing it in a restraining box, and by placing the distracting stimuli in such a position that they are in the center of the field illuminated by the photic stimulus whose evoked potentials are being measured. This insures that, when the rabbit orients toward the distracting stimuli, it will be maximally exposed to the photic stimulus, thus tending to reduce the problem of eye and head movement.

(c) To compare the effects that a visual distracting stimulus has on the evoked potential with those of a distracting stimulus in another sensory modality (audition).

(d) To compare the changes in amplitude of the evoked potentials produced by an external stimulus with those obtained when the potentials are evoked by submaximal electrical stimulation of the optic chiasma.

(e) To compare the amplitude of evoked potentials produced, when the stimulus which evokes the potential (flash from a photographic flash unit or optic chiasma stimulus) is given alone, with those produced, when that potential evoking stimulus is paired with a noxious stimulus (white noise).

B. Apparatus

1. Stereotaxic Apparatus.

A Trent H. Wells modification of the Horsley-Clarke stereotaxic apparatus with a rabbit adaptor was employed. The stereotaxic atlas of Sawyer, Everett and Green (1954) was used.

2. Electrodes.

Bipolar stainless steel electrodes were used. Two sets of electrodes were implanted in each rabbit; a lateral geniculate body pair for recording purposes and an optic chiasma pair for stimulating purposes.

The electrodes were made from 00 stainless steel insect pins. A short 1 inch No. 36 insulated copper wire was soldered to the electrode 4 mm. from the external end. The electrode and solder junction were then dipped in Insl-XE-33 clear lacquer and allowed to dry for a period of 24 hours.

Prior to surgery approximately 0.5 mm. of insulation was removed from one side of the electrode tip with a sharp scalpel blade. During implantation, the electrodes were held in a rigid parallel position, 2 mm. apart.

3. Cerebral Cortex Leads.

The cerebral cortex leads were prepared from size 0-80, stainless steel screws, 1/8" long. There were three in all, for each animal, and they served two functions; one as electrodes recording from the surface of the cerebral cortex, and another, as an anchoring device for the amphenol socket (see below). Two screws acted as recording electrodes and the third provided a ground lead to the animal.

Each screw was prepared by soldering a one inch No. 36 insulated copper wire to the lateral surface of the head.

4. Recording Chamber.

All animals were tested in a recording chamber which consisted of a ventilated sound-reducing box prepared from an old refrigerator, (the interior was lined with one inch styrofoam to provide further sound-reducing effects). The inside was divided into a small and large compartment by a sheet of frosted glass.

A photographic flash unit was placed in the small compartment and faced the glass plate. The flash unit served as the source of the photic stimulation which elicited evoked potentials under peripheral stimulation conditions. The flash unit was triggered by a relay which was driven by a Tektronix type 161 Pulse Generator. The flash unit was mounted in a 14" x 10" x 8" plywood box packed with fiberglass for acoustical insulation. The front wall of this box consisted of a transparent lucite plate. Under the conditions of the experiment the sound produced by the flash unit was not audible to the experimenter.

Mounted on the other side of the frosted glass portion (facing the large compartment), was a three inch loudspeaker and a G.E. NE-40 neon-tube $4\frac{1}{2}$ cm. in diameter. The loudspeaker was used to deliver clicks which acted as the auditory distracting stimulus while the neon-tube produced a flickering light which acted as the visual distracting stimulus. The neon-tube was placed in the center of the frosted glass partition and the loudspeaker was located directly below it, still near the center of the glass. This central location was desirable since it insured that the source of the distracting stimuli would be in the center of the field illuminated by the photic stimulus whose evoked potential was being recorded. In this way, the retina was equally illuminated during distracting and control conditions. The neon-tube and loudspeaker, which provided the distracting stimuli, were energized by pulses from the Hewlett-Packard Type 214A Pulse Generator set at

a pulse repetition rate of 10 cycles per sec., the duration of the pulses being 10 msec.

The entire recording chamber was dimly illuminated by a 15 watt bulb, which was located adjacent to the flash unit, in order to maintain the animal at a photopic level of light adaptation.

A 12" x 12" one way viewing screen was mounted in the door of the recording chamber to enable the experimenter to observe the rabbit during the testing procedure without distracting the animal.

During the recording procedure the rabbit was held in a retaining box which was placed in the large compartment of the recording chamber. The restraining box was positioned in such a way that the center of the frosted glass partition was approximately in line with the visual axis of the animal's right eye. The distance from the rabbit's eye to the frosted glass partition, which was illuminated whenever the flash unit which produced the evoked potential was triggered, was eight inches. This position was uniform for all rabbits.

It should be added that in half the rabbits used in Experiment II, III, and IV, the potentials were evoked by electrical stimulation of the optic chiasma. During this time the rabbit was in the recording chamber in the same position as described above.

During part of Experiment II and III a high fidelity Armaco CT-3 Tweeter was placed in the large compartment to provide noxious stimulation in the form of white noise.

5. Recording Equipment

(a) Pre-amplifier. The Argonaut LEA042 Differential Pre-amplifier was used during recording and implanting procedures. The pass band of the pre-amplifier was set from 1 cycle to 1600 cycles.

During the recording procedure two of these pre-amplifiers were used. The lateral geniculate body electrode leads were connected to one, and the visual cortex leads were connected to the other pre-amplifier by means of single conductor microdot cables.

(b) Cathode Ray Oscilloscope. During implantation of the electrodes the Tektronix Type 502A Dual-Beam Oscilloscope was used to monitor the evoked potentials. It was also connected to a Grass Ultra-Linear Audio Monitor in order to permit auditory monitoring of the evoked potentials.

During the recording procedure a Tektronix Type 564 Storage Oscilloscope equipped with a Type 3A1 Dual-Trace Amplifier and Type 3B3 Time Base Generator was used to display the evoked potentials for amplitude measurement.

(c) Stimulating Equipment. The distracting stimuli produced by the loudspeaker and neon-tube were triggered by a Hewlett-Packard Type 214A Pulse Generator which was gated by a

Tektronix Type 162 Waveform Generator for 2 sec. This first Type 162 Waveform Generator also triggered a second Tektronix Type 162 Waveform Generator which in turn fed a sawtooth wave of 2.5 sec. duration into a Tektronix Type 161 Pulse Generator. At the termination of the sawtooth the Pulse Generator produced the pulse that triggered the flash unit and optic chiasma stimulus. During optic chiasma stimulation the potentials were evoked by a single electrical pulse, of .1 msec. duration, produced by a Tektronix Type 161 Pulse Generator and delivered to the animal through an Argonaut Type LIT069 Isolation Transformer and 420,000 Ohms of resistance. This resulted in a biphasic pulse having a relatively constant peak current of 167 microamperes.

C. Surgical Procedures.

A total of 16 New Zealand white rabbits, weighing between two and three kg. were used. The animals were anesthetized by intravenous injection of Pentobarbitol sodium (about 15-20 mgm/kg) while being held in a restraining box. The anesthetic was started one hour following a subcutaneous injection of Chlorpromazine (15 mgm/kg). The incision site and pressure points were infiltrated subcutaneously with a total of 1 cc of Xylocaine Hydrochloride 2% with Epinephrine 1:100,000. A surgical level of anesthesia was maintained throughout surgery by 5-10 mgm doses of Pentobarbitol sodium at required intervals.

The anesthetized rabbit was then placed in a stereotaxic apparatus and the skull was secured in position. A midline scalp incision was made from the lambda to a point just anterior to the eyes. The skin flaps and periostium were retracted and the bleeding was controlled with pressure. The stereotaxic apparatus and skull were then leveled by means of a circular spirit level. Following the leveling procedure the zero mark on the skull was marked with a sharp lead pencil. The trephine sites, as determined from the atlas, were measured and marked for the lateral geniculate body electrodes, optic chiasma electrodes and visual cortex screws. The trephining was done with a dental drill. The stainless steel screws were screwed into the skull to a depth which allowed the tips to contact the dura mater but not to tear it. The best location for the visual screws was predetermined in a pilot study and was as follows: the two screws used as visual cortex leads were placed over the left visual cortex (10 mm posterior from the bregma and 7 mm lateral from the midline) and over the frontal lobe (5 mm anterior from the bregma and 2 mm lateral from the midline); the third screw formed a ground lead to the animal and was placed over the posterior half of the right cerebral hemisphere in a convenient location.

The bipolar stainless steel electrodes were then implanted in the lateral geniculate body by employing the coordinates in the stereotaxic atlas. The final placement of the electrodes

was determined in the following manner: During the insertion of the electrodes a flashing light (12X per min.) was focused at the open right eye (the eyes were held shut the rest of the time to prevent drying and accidental abrasions of the cornea). The open eye was covered with an opaque plastic dome (one half of a table tennis ball) to disperse the light and insure complete illumination of the retina. Mounted in front of the flashing light was a photocell. The impulses from it were fed into the cathode ray oscilloscope and served to trigger the latter in synchrony with the flashes. The electrodes were connected through the electrode holder to two single conductor shielded cables which passed to the pre-amplifier. Evoked potentials were monitored visually on the oscilloscope, and auditorily by the Grass Ultra-Linear Audio Monitor. In this way implantation could be carried out with a high degree of certainty. The electrodes were then fixed in position by means of dental cement.

The optic chiasma electrodes were implanted in a similar fashion. Their location was further verified by stimulating the optic chiasma with pulses from the pulse generator as described above, and then recording the potentials so evoked, from the lateral geniculate body electrodes by monitoring them on the oscilloscope screen. When satisfactory evoked potentials were demonstrated in this way the electrodes were fixed in position with dental cement.

The rabbit was then removed from the stereotaxic apparatus and a No. 1206-192 Amphenol Plug was mounted into place on the skull and anchored to the screws by means of dental cement. Two of the seven pins in the Amphenol socket were used for recording from the lateral geniculate body, two for stimulating the optic chiasma, two for recording from the visual cortex area, and one pin provided a ground lead. The plug had been prepared earlier by soldering a $\frac{1}{2}$ inch No. 28 insulated copper wire to each of the seven pins. The solder points and pins were insulated with Insl-XE33 Clear lacquer. After the plug was mounted on the skull each electrode lead was soldered to its corresponding lead from the plug. Each lead was then carefully imbedded in dental cement placed around the plug. This provided for a firmly fixed plug and prevented short circuits or movement of the electrodes.

The wound was then swabbed with Sulfathiazole 5% in Plastic Film C.F. The skin flaps were approximated in front of and behind the plug with three wound clips. To further safeguard against infection the animal was given 1 cc of Penicillin and Streptomycin in aqueous suspension intra-muscularly, at the end of the procedure.

There were no post-operative complications and the rabbits would take food and water the following day. Wound healing was always rapid and by first intention. Rabbits appear to be highly resistant to infection. The wound clips were removed on the seventh-eighth post-operative day.

D. Recording Procedure.

The recording of visual evoked potentials was never started before one week after surgery. Beginning on the fourth day post-operative, the rabbit was placed in the restraining box inside the recording chamber for a period of 5-10 mins. each day for 3-4 days prior to the actual recording. This was to permit adaptation to the recording chamber.

All animals had the right pupil atropinized about one hour before the recording procedure.

The actual recording procedures can best be described under the specific experiments carried out.

Experiment I.

Four rabbits were used in this experiment. The potentials recorded from these animals were evoked by a peripheral visual stimulus from the flash unit which was directed at the right eye. The evoked potentials were recorded from the left lateral geniculate body and left visual cortex. The distracting stimuli were of two types; one was auditory (clicks from the loudspeaker), and the second was visual (flickering light produced by the neon-tube).

The procedure followed in this experiment was as follows: The animal was placed in the restraining box and recording chamber about one hour after the right pupil had been dilated with 5% Homatropine Hydrobromide U.S.P. The position of the box in the chamber was kept constant for all the animals and was described above (Apparatus-recording chamber). The socket on the rabbit's skull

was connected to the two Argonaut Type LRA042 Differential Preamplifiers by means of a plug and microdot cables. The dim light in the recording chamber was turned on and the room lights turned out. A standard level of white noise was maintained in the room as a precaution against external auditory stimuli.

The evoked potentials were monitored on the Tektronix Type 564 Storage Oscilloscope. A peak to peak measurement over the first 150 msec. was used as the measure of the amplitude of the evoked potentials. No attempt was made to differentiate between the early and late waves of the evoked potentials in this study. This procedure was used throughout all the experiments. The apparatus was calibrated each day at 200 µv/cm using an Argonaut Type LRG059 Voltage Calibrator.

Each animal was given a block of 24 test stimuli each day for three successive days. Each block was made up of three conditions: the peripheral visual stimulus (flash from flash unit) preceded by the auditory distracting stimulus; the peripheral visual stimulus preceded by the visual distracting stimulus; and the peripheral visual stimulus alone. In this way each test variable was administered eight times each day of recording. The order of presentation of the tests was randomized, with the restriction that each condition occurred an equal number of times. The inter-trial interval was also randomized by means of a Paper Tape Reading Apparatus. The inter-trial interval ranged from 30-160 sec., with a mean time interval of 80 sec.

The auditory and visual distracting stimuli had a duration of 2 sec. and the peripheral visual stimulus occurred 0.5 sec. after the cessation of the distracting stimulus (it was assumed that the process of "attention" outlasts the stimulus by at least 0.5 sec.). Thus, whenever a distracting stimulus was given, the auditory clicks or flickering light went on for a period of 2 sec. to be followed 0.5 sec. later by the flash, from the flash unit, which evoked the visual potential that was measured on the screen of the Tektronix Type 564 Storage Oscilloscope. Unless stated otherwise this was the time schedule followed in all experiments when distracting stimuli were employed.

The peak to peak amplitude of the evoked potential was measured, restricting the measurement to the first 150 msec. after the stimulus.

The rabbit often struggled during the period of time that it spent in the recording chamber. However, by observing the animal through the one way screen in the door of the chamber, the experimenter could avoid presenting the animal with test stimuli at such a time.

Experiment II

In this experiment a total of 12 rabbits were used. The potentials recorded from six of the animals were evoked by a peripheral stimulus (flash) and those recorded from the other six were evoked by a central stimulus (optic chiasma stimulation).

The procedure carried out was as follows: During the first day, those animals that received the peripheral visual stimulus, were given a total of 30 test treatments. There were again three treatment

conditions, the same as those used in Experiment I. On the second day no measurements were taken, instead, the rabbits were exposed to a procedure in which the animal received 30 exposures to the 2 sec. flickering light followed immediately by 2 sec. of white noise at an intensity of 98 db. (The intensity of the white noise was measured by placing a General Radio Co. Type 1551-C Sound-Level Meter inside the recording chamber under experimental conditions.)

This procedure will be referred to as a conditioning procedure, hereafter, even though it is not "classical conditioning" in the true sense of the word since no overt responses were measured to determine if conditioning had occurred. The animals received no further treatment that day. On the third day each animal was exposed to the same procedure as on the first day of testing. The high-fidelity "tweeter" that had been used to produce the white noise the previous day was removed from the recording chamber in order to guard against any distracting effects it might have on the animals.

The other six animals receiving the central stimulation (optic chiasma) were tested in the same manner. Care was taken to insure that all conditions were kept constant except for the replacement of the peripheral stimulus, which evoked the potentials, with the central stimulus.

Experiment III

A total of six rabbits were used in this study, with three animals in the peripheral stimulus group and three in the central stimulus group. The animals had been used in Experiment II. On

the first day, a base line was established by measuring the evoked potentials obtained from five trials with the peripheral or central stimulus alone. These five trials were followed by a total of 25 trials in which the stimulus which evoked the potential (from now on referred to as potential evoking stimulus) was coupled with a noxious stimulus (white noise).

On the second day the procedure was further altered in the following manner. The animals received a total of 20 test trials. During the first and last five test trials the peripheral or central stimulus was coupled with the noxious stimulus. During the middle ten test trials, however, a visual stimulus (the flickering light) of 2 sec. duration preceded the potential evoking stimulus which was again coupled with the noxious stimulus.

E. Histological Verification of Electrode Position.

At the end of the study each animal was anesthetized, as described above, and the marking of electrode sites was carried out. This was done with a Lesion Generating Device (Cat. No. 58040 - C. H. Stoelting Co.). A current of 2.5 milliamperes was passed through each electrode for a period of 2 sec. duration with the electrode connected to the positive pole of the Lesion Generating Device. This was sufficient to deposit iron molecules in the brain tissue at the tip of the electrode.

The animal was then perfused by injecting Mammalian saline into the left ventricle after an incision had been made in the

right atrium of the heart. This was followed by injecting Formalin (10%) containing Potassium Ferrocyanide (2%). The Potassium Ferrocyanide combines with the iron that has been deposited to produce a Prussian Blue stain on histological section.

Serial sections 50 u thick were made with a AO Spencer Model 880 Automatic Laboratory Model Microtome (freezing was done with dry ice). The sections were mounted and stained, using a Nissl stain. This provided final verification of electrode placement.

Results

The results can best be presented under the various experiments carried out.

Experiment I.

A total of 288 evoked potentials were recorded and measured from the visual cortex and lateral geniculate body in this study. The statistical analysis was done on the mean of the eight evoked potentials for each day under each condition.

By an analysis of variance the only significant effect was the main effect corresponding to the stimulation conditions. By the Duncan Multiple Range test (Edwards, 1960), the amplitudes of the cortical evoked potentials obtained following auditory or visual distraction were significantly smaller than the control condition ($P < .01$). There was no significant difference between the depressing effects produced by the auditory and visual distracting stimuli. These means are shown in Table 1.

The recordings obtained at the lateral geniculate body were similar. There was a depression of the evoked potentials when the distracting stimulus preceded the stimulus which evoked the potential as compared with the potentials recorded when that stimulus was given alone. By an analysis of variance and the Duncan Multiple Range test the amplitudes of the evoked potentials obtained following auditory or visual distraction were likewise significantly smaller than those obtained under control conditions ($P < .01$). Again, there was no significant difference between the two distracting stimuli. These means are likewise shown in Table 1.

TABLE 1

MEAN PEAK TO PEAK AMPLITUDES (IN MICROVOLTS) OF THE EVOKED POTENTIALS RECORDED FROM THE VISUAL CORTEX AND THE LATERAL GENICULATE BODY UNDER THE THREE STIMULATING CONDITIONS. THE LINES AT THE BOTTOM OF THE TABLE INDICATE THE DIFFERENCES WHICH WERE SIGNIFICANT AT THE .01 LEVEL

	Visual Cortex			Lateral Geniculate Body		
	Control Condition	Auditory "Distraction"	Visual "Distraction"	Control Condition	Auditory "Distraction"	Visual "Distraction"
Mean Evoked Potentials (microvolts)	330	266	281	392	348	362

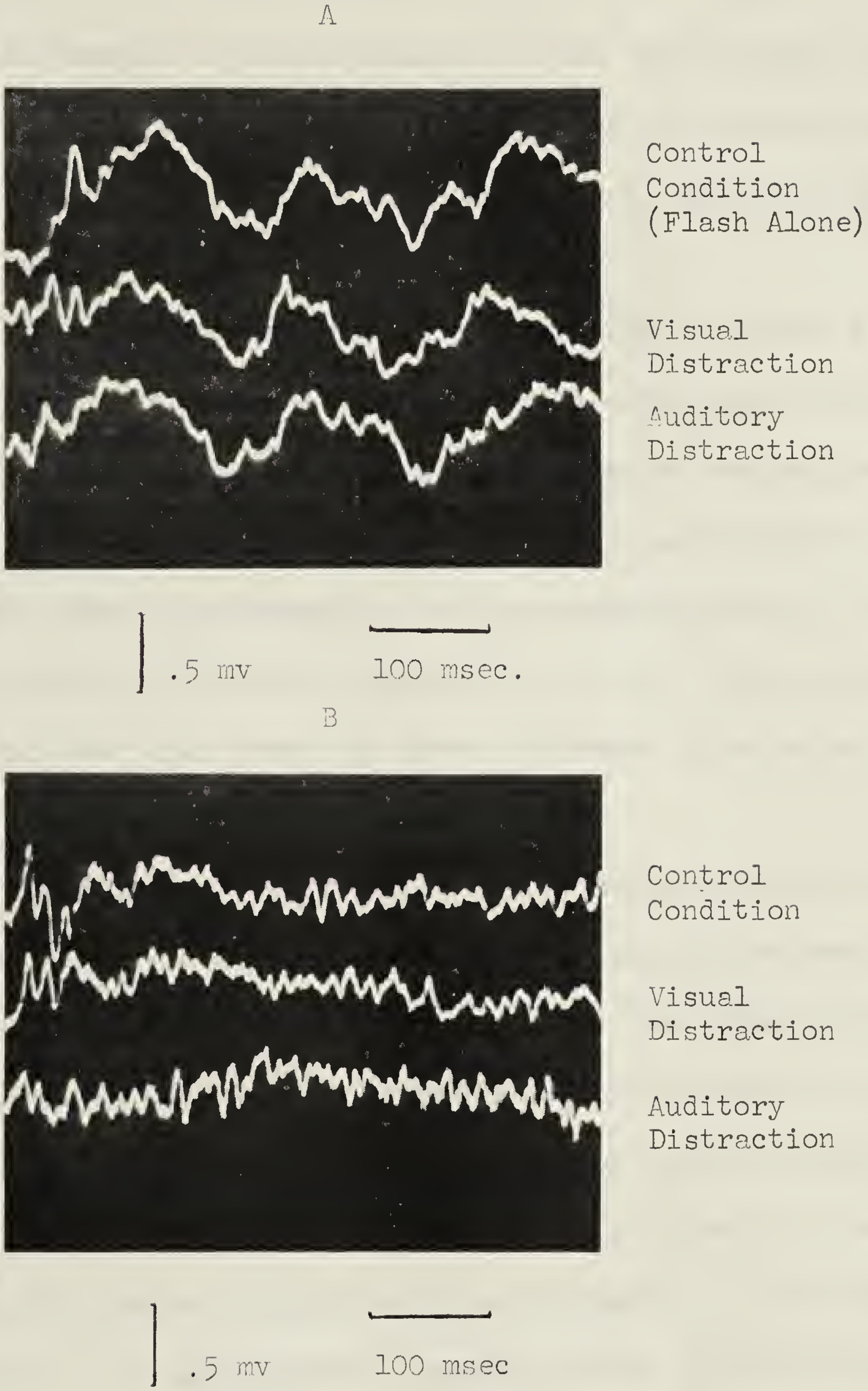

Fig. 1. Oscilloscope records illustrating the depressing effect of visual and auditory distraction upon the visual evoked potentials at the visual cortex (A) and lateral geniculate body (B).

An example of the depression of the visual evoked potentials which was observed at the visual cortex and lateral geniculate body during the distracting conditions is shown in Fig. 1.

Experiment II

The 12 rabbits tested in this experiment yielded a total of 720 evoked potentials from the visual cortex and lateral geniculate body. The statistical analysis was carried out on the means of 10 evoked potentials for each day under each condition. The mean amplitudes, in microvolts, of the evoked potentials obtained, with peripheral and central stimulation, at the visual cortex and lateral geniculate body under the three different stimulation conditions are tabulated in Table 2.

By an analysis of variance and by applying the Duncan Multiple Range test the difference between peripheral and central stimulation failed to reach significance either at the visual cortex or lateral geniculate body level. In addition, the interaction between the site of stimulation and the stimulation conditions was not significant. In other words, the evoked potentials produced by a central stimulus (optic chiasma stimulation) were depressed, by the "distracting" stimuli, to approximately the same degree as were the evoked potentials produced by a peripheral or retinal stimulus (flash of light). This finding is demonstrated in Fig. 2. By an analysis of variance the only significant effect was the main effect corresponding to the stimulation conditions. By the Duncan Multiple Range test the depressing effect of the auditory and visual distracting stimuli

TABLE 2

MEAN PEAK TO PEAK AMPLITUDES (IN MICROVOLTS) OF THE EVOKED POTENTIALS RECORDED FROM PERIPHERAL AND CENTRAL STIMULATION AT THE VISUAL CORTEX AND LATERAL GENICULATE BODY UNDER THE THREE DIFFERENT STIMULATING CONDITIONS. THE LINES AT THE BOTTOM OF THE TABLE INDICATE THE DIFFERENCES WHICH WERE SIGNIFICANT AT THE .01 LEVEL.

	Visual Cortex			Lateral Geniculate Body		
	Control Condition	Auditory "Distraction"	Visual "Distraction"	Control Condition	Auditory "Distraction"	Visual "Distraction"
Peripheral Stimulus (flash)	310	214	230	256	199	199
Central Stimulus (Optic Chiasma Stimulation)	322	218	220	288	216	217

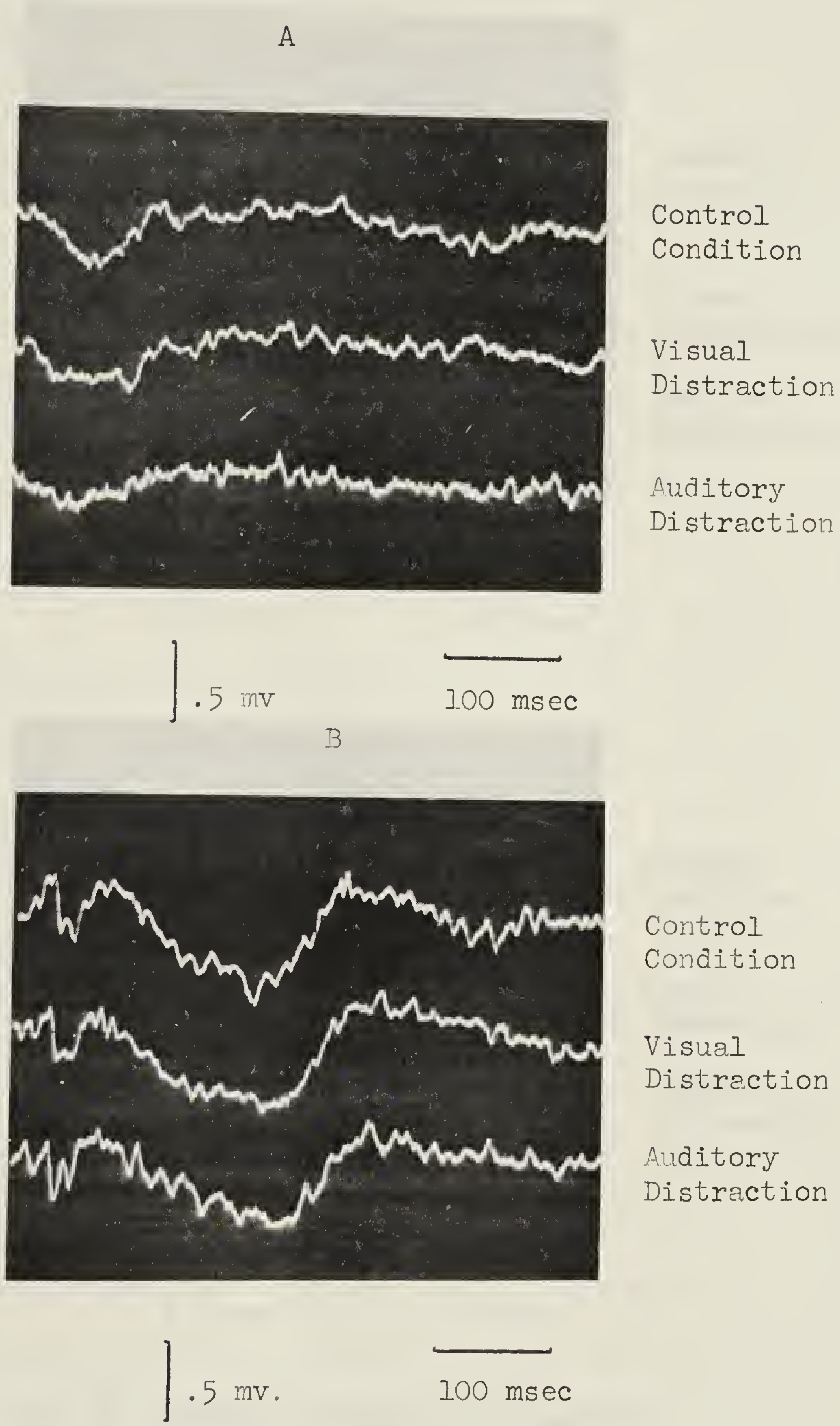

Fig. 2. Effect of visual and auditory distraction upon cortical evoked potentials which are produced by central stimulation (A - optic chiasma stimulation), and peripheral stimulation (B - flash of light).

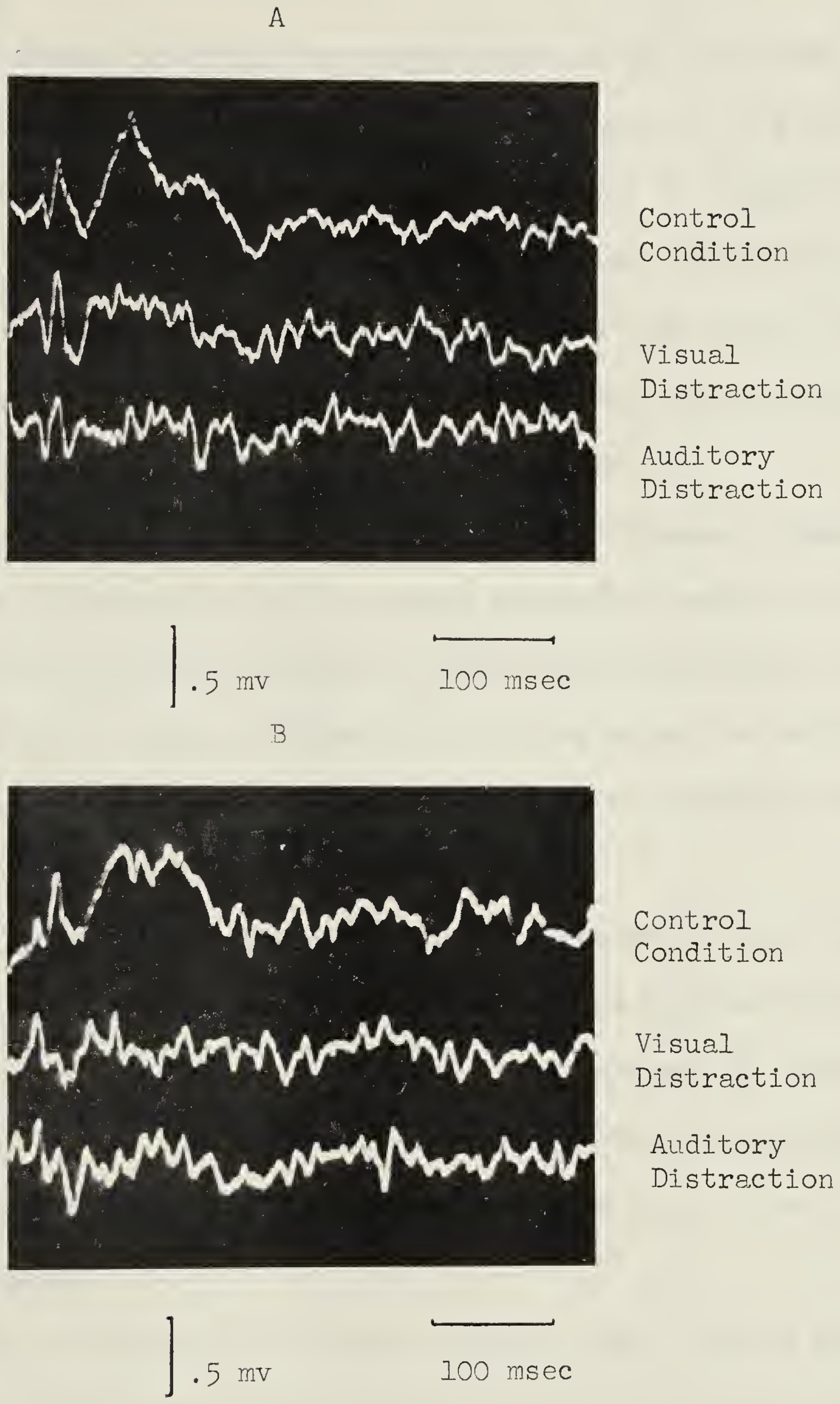

Fig. 3. Effect of visual distraction upon the cortical evoked potentials, one day before (A) and one day after (B) conditioning the visual distracting stimulus with a noxious stimulus.

on the evoked potential was significant at the .01 level for both the visual cortex and lateral geniculate level. This further supports the findings obtained in Experiment I. Again, by Duncan Multiple Range Test, there was no significant difference, either at the visual cortex or lateral geniculate body level, between the degree of depression of the evoked potentials, produced by the auditory and visual "distracting" stimuli.

Similarly, there was no significant difference between the amount of depression of the evoked potentials caused by the visual distracting stimulus before the conditioning procedure, and that caused by the visual distracting stimulus after the conditioning procedure. An example of this finding is illustrated in Fig. 3.

Experiment III

A total of 210 evoked potentials, recorded at the visual cortex and lateral geniculate body from the six rabbits studied in this experiment, were analysed. The analysis of variance was applied to all the recordings obtained in this study, rather than to the means of the recordings, as was the case in the two previous experiments.

The results at the visual cortex on day 1 of the experiment indicate that when noxious stimulus (white noise) was coupled with the potential evoking stimulus ("attention" condition) there was a depression of the evoked potentials compared with those obtained when the potential evoking stimulus is presented alone. This difference was significant at the .01 level. On day 2 there was

TABLE 3

MEAN AMPLITUDES (IN MICROVOLTS) OF THE EVOKED POTENTIALS RECORDED FROM THE VISUAL CORTEX AND THE LATERAL GENICULATE BODY UNDER THE THREE DIFFERENT STIMULATING CONDITIONS

	Day 1		Day 2	
	Control Condition	"Attention" Condition	"Attention" Condition	"Warning" Condition
Visual Cortex	302	230	163	234
Lateral Geniculate Body	242	206	214	204

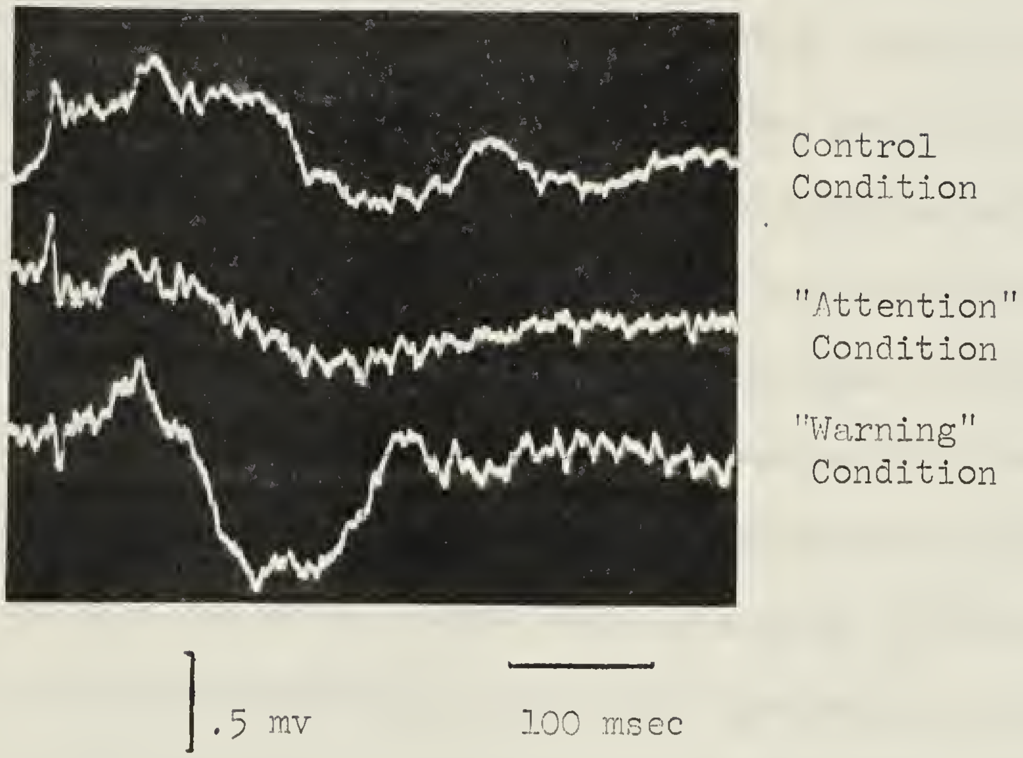

Fig. 4. Comparison effect of "Attention" Condition (potential evoking stimulus is paired with noxious stimulus) and "Warning" Condition (flickering light preceding the potential evoking stimulus and noxious stimulus) upon the cortical evoked potentials.

a marked enhancement of the evoked potentials recorded during the "warning" condition (flickering light precedes the "attention" condition) as compared to the evoked potentials recorded during the "attention" condition alone. In other words, when the flickering light preceded the potential evoking stimulus coupled with white noise there was an enhancement of the evoked potentials as compared to the evoked potentials recorded when the potential evoking stimulus coupled with white noise was not preceded by the flickering light. A typical example of these findings for day 1 and day 2, under the three conditions is illustrated in Fig. 4. By an analysis of variance this difference was significant at the .01 level. These means are shown in Table 3.

The results obtained at the lateral geniculate body for day 1 were similar to those obtained at the visual cortex. The difference was significant at the .01 level. There was no significant difference, however, between the "attention" condition and the "warning" condition at the lateral geniculate body. These means are shown in Table 3. A word should be said about the various stimulating conditions referred to in Table 3: Control Condition, refers to the potential evoking stimulus alone (flash or optic chiasma stimulation); "Attention" Condition, refers to the condition when the noxious stimulus (white noise) is coupled with the potential evoking stimulus; "Warning" Condition, refers to the condition when the warning stimulus (flickering light) precedes the "Attention" Condition.

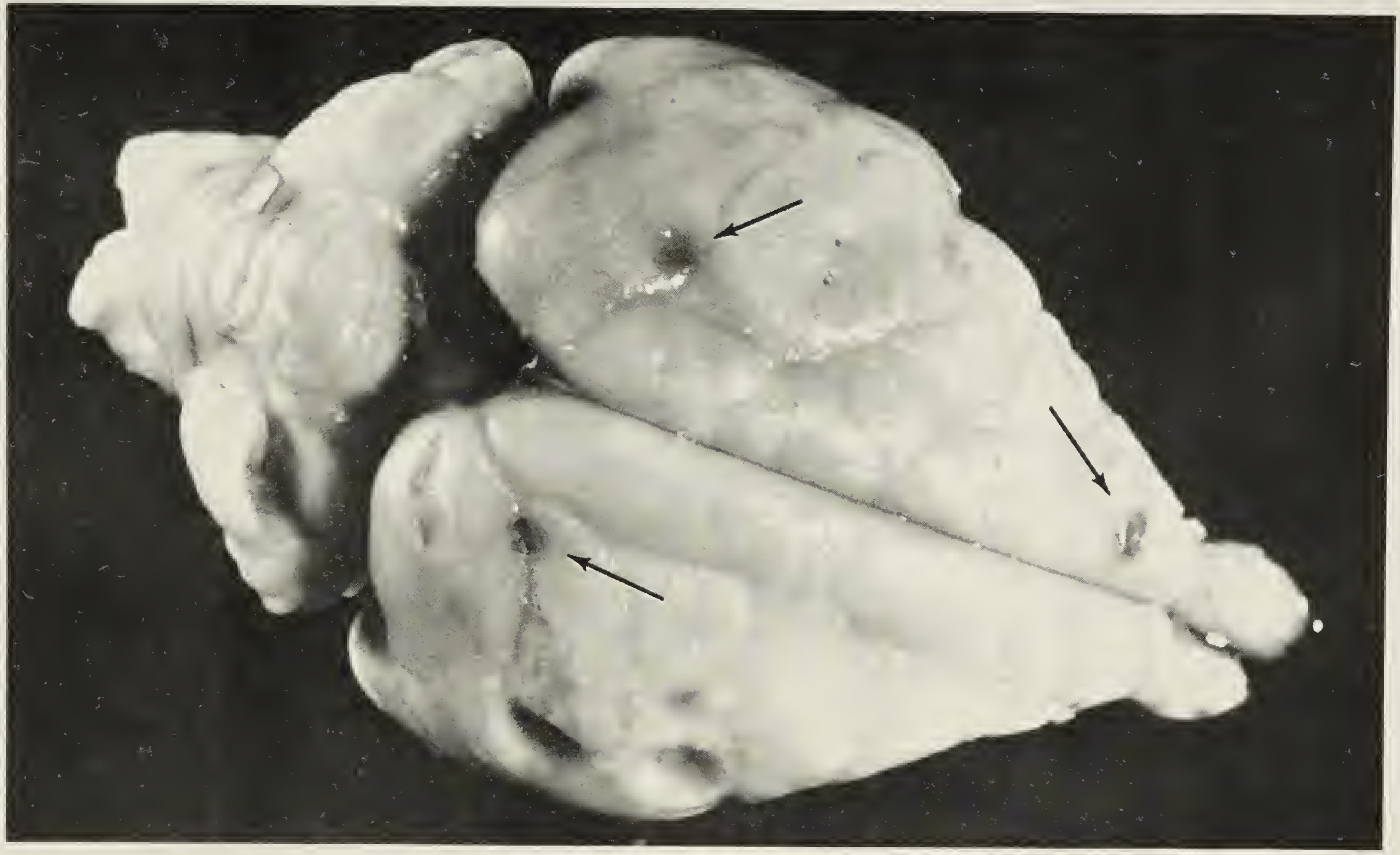

Fig. 5. The dorsal surface of the rabbit brain (x5). Top two arrows indicate the location of the cortical screws used to record cortical evoked potentials (posterior screw - left visual cortex; anterior screw - indifferent electrode). Lower arrow indicates the location of the cortical screw which acted as the ground lead.

As was stated earlier, the final electrode location, in each animal, was verified histologically. Fig. 5 illustrates the typical location of the topical visual cortex leads. Fig. 6 demonstrates the location of the tips of the optic chiasma electrodes which were used to stimulate the visual pathway centrally, thus bypassing the peripheral mechanisms of the visual system. The lateral geniculate body electrode sites were demonstrated microscopically by means of histological sections, Fig. 7.

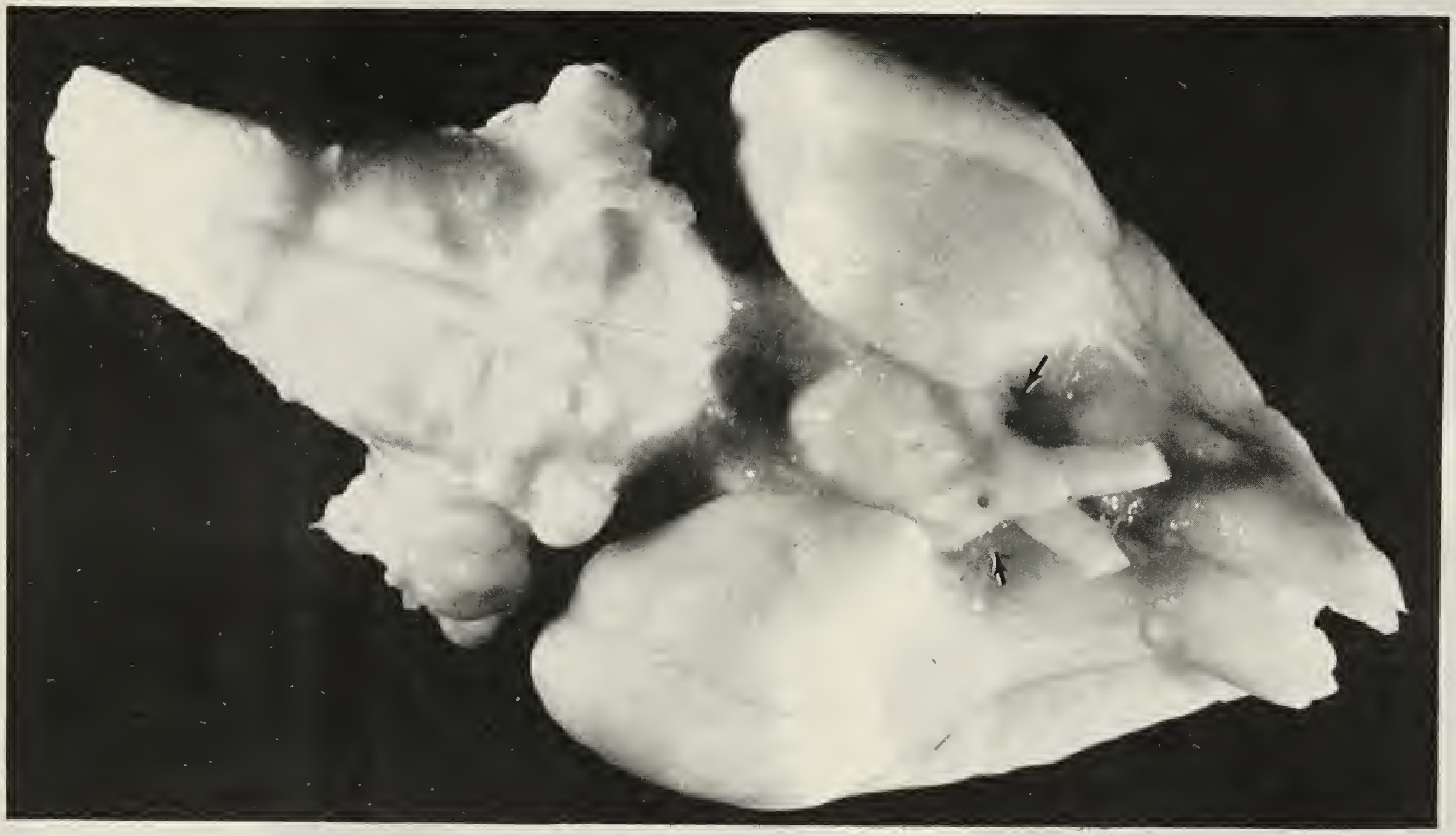

Fig. 6. The ventral surface of the rabbit brain (x5). The arrows indicate the location of the optic chiasma electrodes (used for central stimulation) within the optic chiasma.

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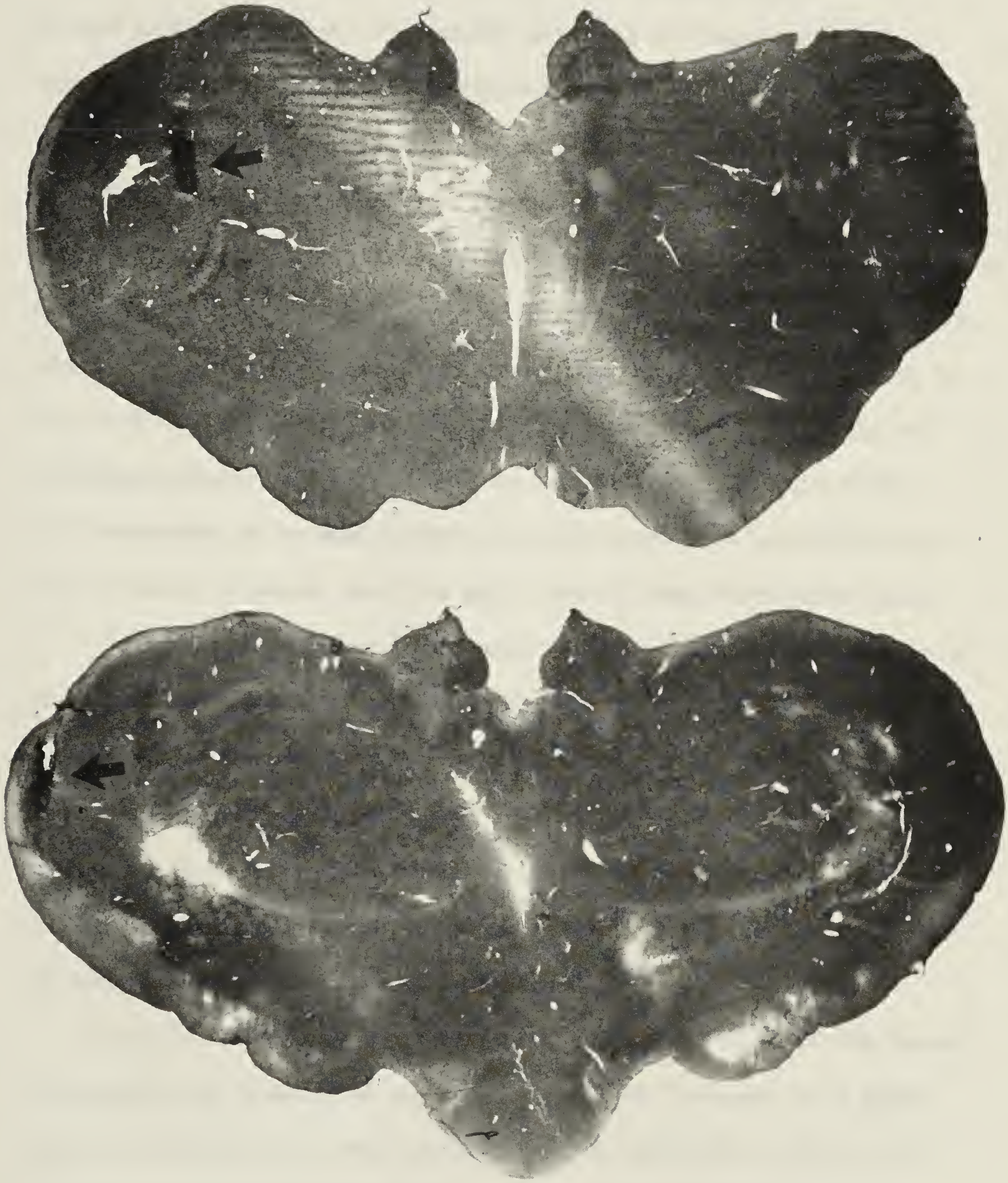

Fig. 7. Microscopic slides of the lateral geniculate body region (low power). Top slide illustrates the location of the medial electrode, while the bottom slide illustrates the location of the lateral electrode within the lateral geniculate body.

Discussion

An analysis of the data from previous studies, leads one to the conclusion that the results obtained in these experiments can be explained in several different ways. At least four possible explanations may be advanced.

The first such hypothesis is that the observed alterations in evoked potentials associated with the behavior phenomena of "attention" and "distraction" can be accounted for in terms of peripheral mechanisks, i.e., orientation of the eyes, pupillary changes, closing of the eyelids, etc. This idea gained support from the findings of Fernández-Guardiola et al.,(1961) on habituation. In this study the depression of evoked potentials associated with visual habituation failed to occur when the pupil was dilated with Homatropine.

Perhaps the simplest hypothesis is that the observed depression in evoked potentions associated with a shift of "attention" or "distraction" is merely the result of any increase in the general arousal state. Horn (1960), can be considered as the chief proponant of this view. His findings indicated that once the animal failed to demonstrate any orienting behavior the typical depression of evoked potentials ceased to occur.

A third and somewhat more complex hypothesis is that the evoked potentials are attenuated during "distraction" because of a gross selective mechanism. This gross selective mechanism would cause a generalized facilitation of the whole sensory modality whenever a shift of attention occurs. In other words, whenever a "distraction"

causes a shift of "attention" from the visual modality to, say, the auditory modality there is a generalized inhibition of the visual system and a facilitation of the auditory system.

An even more complex hypothesis is that which was advanced by Hernández-Péon and his associates (Palestini, Davidovich, and Hernández-Péon (1959). This hypothesis proposes that there exists a central selective filtering mecahnism which "edits" all afferent sensory impulses within each sensory pathway. Thus, there would be an inhibition of impulses arising from one visual stimulus and a selective facilitation of the impulses arising from another visual stimulus to which the subject was "paying attention". The work of Palestini, Davidovich, and Hernández-Péon (1959), suggests that a centrifugal inhibitory mechanism acting upon subcortical portions of the visual pathway, and in which the brain stem reticular system plays an important role, does operate during "attention" and "distraction". However, as was pointed out earlier, the exact site of action of these centrifugal impulses is still in doubt. Hernández-Péon and his associates, postulated that this site of action is at the retina as is the case in audition. In audition the cochlea is known to be influenced by centrifugal fibers. Anatomically, the Olivo-cochlear tract was identified by Rasmussen (1954), while Galambos (1954), verified the existence of these centrifugal fibers physiologically.

The present results provide some evidence for and against these four hypotheses, and also suggest a need for further investigation in some areas.

Certainly, the results verify the fact that the depression in amplitude of visual evoked potentials associated with "distraction" does occur in rabbits as well as in cats.

The finding, that there is no significant difference in the amount of depression of evoked potentials, produced by a distracting stimulus, when that distracting stimulus precedes a peripheral or central potential evoking stimulus indicates that the hypothesis of a peripheral mechanism should be rejected. If peripheral factors were involved one would expect, perhaps, a greater depressing effect when the retina is stimulated by the flash from the photographic flash unit. Instead, it was of the same order of magnitude as that observed when the peripheral organs were bypassed and the optic chiasma was stimulated directly.

This finding may also provide important indirect evidence concerning the functional importance of any centrifugal fibers which may terminate in the retina. As postulated by Hernández-Péon et al, 1956, the centrifugal fibers terminate in the retina which enables the retina to function as a peripheral filtering mechanism to incoming visual information. Palestini et al, 1959, further postulated that the retinal changes observed during shift of attention result from the action of centrifugal inhibitory and facilitatory fibers to the retina. The present findings fail to demonstrate that the retina possesses such filtering properties. Instead, the results indicate that the filtering mechanism operates at some level beyond the retina since both types of stimuli (flash

and electrical stimulus) are handled in the same manner. Future investigations may help clarify this rather controversial aspect of the specific filtering hypothesis.

The view that the depression of the evoked potentials which occurs during "distraction" may be due to a gross selective mechanism which facilitates one sensory modality and inhibits another can be regarded as invalid in view of the present findings. If this hypothesis was correct one would not expect the visual "distracting" stimulus to have a depressing effect on a visual evoked potential. In other words, the depression of visual evoked potentials should only occur when there is a shift of "attention" which causes the involvement of some other sensory modality, other than vision, such as the auditory, olfactory or somatic sensory modality. However, the results from the above experiments indicate that the visual distracting stimulus (flickering light) was as effective in depressing the evoked potentials as the auditory distracting stimulus (clicks from loudspeaker). This indicates that the inhibiting effect of a "distracting" stimulus operates selectively within a given sensory modality rather than on a gross generalized basis.

The argument could be advanced, however, that the depression in the evoked potentials associated with the visual distracting stimulus, in the above experiment, is only negative evidence in support of the specific filtering hypothesis. Could one be sure, for instance, that the rabbit was, in fact, paying "attention" to

the distracting stimulus and thus result in an enhancement of the responses to the distracting visual stimulus and a depression of the responses to the potential evoking stimulus? The reason one could not be certain that the animal was paying "attention" is that the flickering light was not a meaningful stimulus to the rabbit (such as a mouse is to a cat). Rabbits, evidently, utilize visual cues very little to gain sensory information about their environment. The ideal way to determine whether or not the animal was attending to the distracting visual stimulus would have been to record and measure the evoked potentials produced by the flickering light itself. However, the amplitude of these potentials was too small to measure reliably. To ensure that the rabbit did "pay attention" to the visual "distracting" stimulus the second day of Experiment II was designed to condition the animal to look at the flickering light by coupling it with a noxious stimulus (white noise). The fact that there was no difference in the degree of depression of the evoked potentials due to the visual distraction, before and after the conditioning process, suggests that if the conditioning procedure is effective in producing "attention" to the stimulus, the animals were probably also attending to the stimulus prior to the conditioning procedure.

The results of day one in Experiment III were rather unexpected. An analysis of the results showed that there was a significant depression of the evoked potentials when the animal was presumably forced to pay "attention" to the potential evoking stimulus (flash or optic

chiasma stimulus) by coupling it with white noise. All other reported studies on such conditioning procedures had indicated that there is an enhancement of the evoked potentials. A possible explanation is that in Experiment III the animal had no possible way of learning when the potential evoking stimulus would occur because the inter-trial intervals were randomized. Therefore, even by coupling the potential evoking stimulus with white noise an increase in "attention" was impossible since it occurred so suddenly and only lasted momentarily. On the face of it the results of day one, therefore, supported the general arousal hypothesis.

Day two of Experiment III was designed to double check the results from day one. It was reasoned that if the animal could be given a warning stimulus a shift of attention to the potential evoking stimulus might be accomplished. The results of day two indicate a significant enhancement of the evoked potentials produced by either the flash or the optic chiasma stimulus. This enhancement appears to be specific evidence against the general arousal hypothesis, and must be considered as further supporting evidence in favor of the selective filtering hypothesis. This conclusion must be limited to the visual cortex, however, since this significant enhancement of the evoked potentials was not found at the lateral geniculate body level.

The fact that an enhancement of evoked potentials did occur, is evidence that this method of producing a shift in "attention"

is effective. Since basically the same procedure was used in Experiment II it is likely that this conditioning procedure was also effective. This tends to validate the previous assumption that the animal was paying "attention" to the visual distraction in Experiment II. Therefore, the depression of evoked potentials which was evident following the visual distraction, in Experiment II, provides evidence in favor of the specific selective filtering hypothesis and evidence against the gross filtering hypothesis.

In summary, the findings from the present study suggest that peripheral mechanisms do not play an important role in the processes involved in the phenomena of "attention" and "distraction". It would also appear that the results provide more evidence in favor of the hypothesis of a specific sensory filtering mechanism than they do for the hypothesis of a gross filtering mechanism or the general arousal hypothesis.

Conclusions

1. Using unanesthetized rabbits, and recording from chronically implanted electrodes, in the lateral geniculate body and visual cortex, a depression of visual evoked potentials was observed under conditions which would be likely to produce shifts of attention in humans. In the analysis of the evoked potentials the peak to peak amplitude over the first 150 msec. was measured. No attempt was made to differentiate between the early and late waves of the evoked potentials.

2. When a noxious stimulus paired with the visual stimulus which produced the evoked potential (flash or optic chiasma stimulation) was presented at random intervals a depression of evoked potentials was observed. However, when the above stimulus was preceded by a warning stimulus (presumably this caused the animal to "attend" to the potential evoking stimulus) significantly less of a depression, or an enhancement, of the evoked potentials was observed.

3. The results from the present study provide evidence which suggests that peripheral mechanisms, such as eye movement, and closing of the eyelid, etc., do not play a role in the processes involved in these phenomena.

4. The results provide evidence which suggests a greater likelihood that the processes involved, are controlled by a specific sensory filtering mechanism which operates via centrifugal fibers in the visual pathway, rather than by a gross filtering mechanism, or by a general arousal mechanism.

5. The results also provide indirect evidence which suggests that if these centrifugal fibers terminate in the retina they do not appear to play an important role in these phenomena.

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